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A Critical Review: The Implementation of Spectrogram and Sonic Visualizer on The Performance Review of Classical Music

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Abstract: This Study examines the implementation of spectrogram and Sonic Visualizer tools in the performance analysis of classical music. Traditional methods of performance feedback often rely on subjective verbal criticism, which can be inconsistent and influenced by personal biases. This study highlights the limitations of these traditional approaches and the challenges posed by reliance on memory. Spectrograms and Sonic Visualizer provide objective, visual feedback that can reveal intricate patterns and details in musical performances not easily discernible through auditory perception alone. These tools offer precise feedback on pitch and timing, which is especially beneficial in educational settings. The study analyzes four key articles: Yasushi Ueda's investigation of tempo *rubato* in Chopin's Nocturne Op.15-2, Cook & Leech-Wilkinson's guide to Sonic Visualizer, Garner's thesis on Schubert's Winterreise, and Gardiner and Latartara's examination of Beethoven's "Hammerklavier" sonata. These studies demonstrate how features such as tempo and dynamic visualization, harmonic analysis, and beat detection aid performers in evaluating rhythmic accuracy, consistency, and interpretative choices. Moreover, the review identifies gaps in existing research, particularly the need for more comprehensive studies on the effectiveness of Sonic Visualizer across different classical instruments and its impact on performers' interpretative skills. The findings suggest that regular use of these tools can enhance performers' decision-making processes, creativity, and overall artistic growth. This study underscores the significant benefits of integrating advanced audio-visual tools into classical music performance analysis, providing a deeper understanding and more accurate assessment of musical interpretations.

Keywords: spectrogram, sonic visualizer, analysis of classical music

1. INTRODUCTION

Most musicians seek guidance from an expert in their instrument, who possesses greater expertise in evaluating musical quality, identifying areas for improvement, and recommending successful training methods. Receiving verbal criticism or feedback from experienced and highly skilled musicians is a conventional and highly regarded approach to enhancing the skills of performers (J. Hattie & Timperley, 2007). However, verbal feedback is inherently subjective and influenced by the master's personal biases, preferences, and interpretations. This can lead to inconsistencies and varying advice, which might confuse the performer, especially if they receive feedback from multiple masters (T. Hattie, 2007).

The importance of deliberate practice and how reliance on memory plays a critical role in the acquisition of expert performance. Memory reliance on performers and its impact on the effectiveness of feedback has been discussed in various studies and articles (Ericsson et al., 1993) (Hallam, 1997) (Ericsson, 2006).

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However, in the traditional approaches, performers must depend on their memory to absorb and apply the feedback given during lessons. The impact of forgetting or misremembering important information or subtle instructions can diminish the usefulness of the feedback. By understanding the challenges associated with memory reliance and employing strategies to mitigate these issues, performers can enhance the effectiveness of the feedback they receive and improve their overall performance. Classical music performers must broaden their musical abilities, frequently without the benefit of personal aural evaluations of sound quality. This makes it difficult for them to tell the difference between effective and ineffective training.

Spectrograms in music provide a new understanding of sound and music by providing visual displays of sound in music (Gardiner & Lim, 2014). These images allow a music theorist or musicologist to combine the analytic procedures of music with those of acoustic physics (Cogan, 1984). This visual information can reveal patterns and details that are not easily discernible through audio alone. Audio visual tools provide precise feedback on pitch and timing, allowing performers to identify and correct inaccuracies more effectively than by ear alone. This can be particularly useful in educational settings where students are learning to master their instruments (McAdams & Bigand, 1993).

According to Cook & Leech (Cook & Leech-Wilkinson, 2009a), spectrograms offer a detailed visual analysis of the harmonic content, overtones, and spectral features of performance, aiding in a deeper interpretation and understanding of the music. This is beneficial for composers, musicologists, and performers aiming to analyze complex pieces. Brown & Puckette (Brown & Puckette, 1992) stated that Audio visualizations are potent educational tools that offer performers clear visual help to comprehend theoretical topics and practical procedures. They aid in the visualization of concepts such as harmony, rhythm, and dynamics. Utilizing audio-visual tools such as a sonic visualizer or spectrogram offers numerous benefits compared to relying just on auditory perception, especially in the area of music performance. Spectrograms and other visual tools display the frequency, intensity, and duration of musical elements, helping performers and listeners understand the intricate structure of the music.

Spectrograms can indeed be employed as tools to identify the standards of performance and interpret the works of important performers. This analytical approach provides a detailed visual representation of the audio signal, highlighting various aspects of the performance that contribute to the overall quality and style. According to Clayton (Clayton, 2020), spectrograms offer a precise and objective method to analyze the frequency, intensity, and timing of musical notes, allowing for an accurate assessment of a performer's technical proficiency. In addition, Spectrograms can reveal unique characteristics of a performer's style, such as their use of vibrato, dynamics, and articulation, which are often difficult to quantify through audio perception alone. By comparing spectrograms of different performances, one can identify the standards and variations in interpretation among different performers, providing insights into what is considered exemplary in various contexts (Repp, 1992).

While Sonic Visualizer offers various features for analyzing performances. However, there is limited research on how effective these tools are across different classical instruments. There is a need

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for more comprehensive studies that evaluate the efficacy of Sonic Visualizer's features (such as spectrogram view, pitch analysis, and beat detection) for different classical instruments (e.g., piano, violin, cello, voice). Each instrument has unique characteristics, and understanding how these features can be optimally utilized for each could significantly enhance performance analysis and educational methodologies. In addition, there is a gap in research on the impact of using Sonic Visualizer to study and compare multiple interpretations on performers' development of their interpretative skills. Studies could investigate how regular use of Sonic Visualizer influences performers' decision-making processes, creativity, and overall artistic growth.

To provide a comprehensive understanding of Sonic Visualizer and its potential impact on classical music performance, a review of relevant literature is essential. This investigation will encompass a wide range of sources, including scholarly articles, books, and professional opinions from renowned musicians and music educators. By critically analyzing existing research and discussions on the subject, we aim to identify the key arguments and perspectives surrounding the use of Sonic Visualizer as a tool for classical performers. This study seeks to the contrasting viewpoints regarding the integration of technology in classical music practice. This exploration will involve examining the historical context of technological advancements in music, as well as contemporary debates on the balance between tradition and innovation in music.

2. METHODS

The review of this study covers four articles. The first, Yasushi Ueda (Ueda, 2021) article titled "Tempo Rubato as Rhetorical Means: An analysis of The Performance of Chopin's Nocturne Op.15-2 By Camille Saint-Saëns" Investigated Camille Saint-Saëns's piano performance of Chopin's Nocturne *Op*.15 No.2 based on the phenomenon the Chopinesque tempo *rubato* in Nocturne Op.15-2. In the second, "A musicologist's guide to Sonic Visualizer," Cook & Leech-Wilkinson (Cook & Leech-Wilkinson, 2009a) assert that Sonic Visualizer enables users to enhance the precision of their observations, refine their auditory perception, and explore the intricacies of recordings through the use of fundamental computer-based tools. The third, Garner's (Cook & Leech-Wilkinson, 2009a) thesis examines five songs from Franz Schubert's song cycle Winterreise (1828) by utilizing spectrographic visuals generated through the Sonic Visualizer computer application. The fourth, "Analysis, Performance, and Images of Musical Sound: Surfaces, Cyclical Relationships, and the Musical Work," Gardiner and Latartara (Cook & Leech-Wilkinson, 2009a) examine the performances of Russell Sherman (2000) and Wilhelm Kempff (1965) playing the first movement of Beethoven's "Hammerklavier" sonata on a grand piano.

Each study demonstrates how Sonic Visualizer's features, such as spectrogram visualization, harmonic analysis, dynamic contrast visualization, and frequency distribution analysis, provide valuable insights into various aspects of musical performance. These tools help performers understand and analyze different interpretations, ultimately enhancing their performances through detailed and precise analysis. The study conducted based on two research questions

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1) What are the specific features of Sonic Visualizer that are most useful for classical performers in analyzing recording performances?
   The review of this research question examines how Sonic Visualizer's beat detection and tempo mapping features help performers evaluate rhythmic accuracy and consistency, essential for maintaining the intended tempo.
   The data is reported in the form of visual aids such as screenshots of spectrograms, annotated recordings, and pitch histograms to illustrate the functionality and usefulness of these features.
2) In what ways can Sonic Visualizer aid performers in understanding and analyzing different interpretations of the performance?
   The review discusses how performers can overlay multiple recordings to compare timing, dynamics, and other musical elements visually.
   The data is reported in the form of visual aids such as comparison graphs, dynamic contour plots, and annotated recordings to illustrate how these analyses can be conducted.

By addressing these research questions in a critical review, we provide a detailed and justified analysis of Sonic Visualizer's features and their applications for classical performers. This approach ensures that the review is both comprehensive and practical, offering valuable insights and evidence to support the utility of Sonic Visualizer in the context of classical music performance analysis

3. RESULTS AND DISCUSSION

3.1 Review 1

Yasushi Ueda's (Ueda, 2021) article titled "Tempo Rubato as Rhetorical Means: An Analysiss of The Performance of Chopin's Nocturne *Op.*15-2 By Camille Saint-Saëns" Investigated Camille Saint-Saëns's piano performance of Chopin's Nocturne *Op.*15 No.2 based on the phenomenon the Chopinesque tempo *rubato* in Nocturne Op.15-2. The study uses an open-source application called Sonic Visualizer (version 4.3; Cannam, Landone, and Sandler 2010) to analyze the timing gaps between melody and accompaniment for each eight-note beat within Saint-Saëns' piano roll recordings. The initial phase of Ueda's study is to the converted MIDI data of Saint-Saëns' 1905 piano roll for calculating the duration of each note. Furthermore, the "Sonic Visualizer" was employed to mark the starting points of all notes on every eighth beat and to classify accompaniment and melody as shown in Figure 1.

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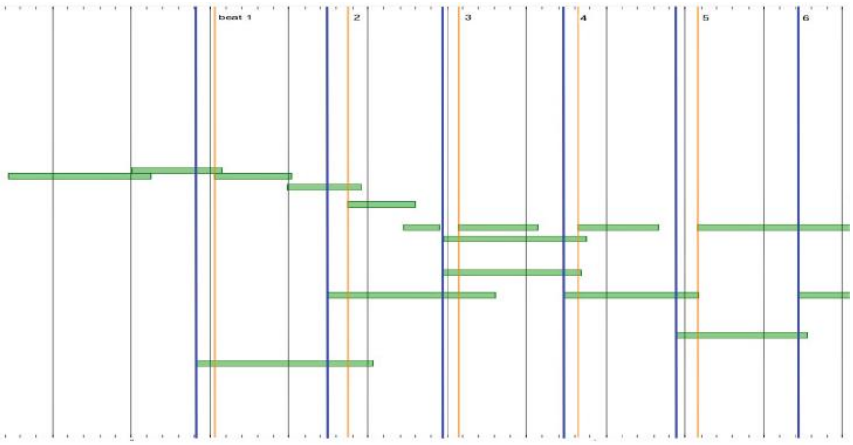


Figure 1. MIDI data are shown by Sonic Visualizer with beat marks in blue for accompaniment and orange for the melody

Ueda's study describes how Saint-Saëns played the delay and precedency of melody about the accompaniment was skilfully controlled according to the construction of phrases and periods, alongside the expressive elements of the piece. From this point of view, the tempo *rubato* can be classed as one of two types: phrasing *rubato* and expressive *rubato*. In the performance of Nocturne *Op*.15 no.2 by Saint-Saëns, the phrasing *rubato* makes phrases and periods recognizable as shown in figures 3 and 4 whereas the expressive *rubato* is concerned with accentuation, emphasis of modulation, imitation of cantabile style, and lamento expression.

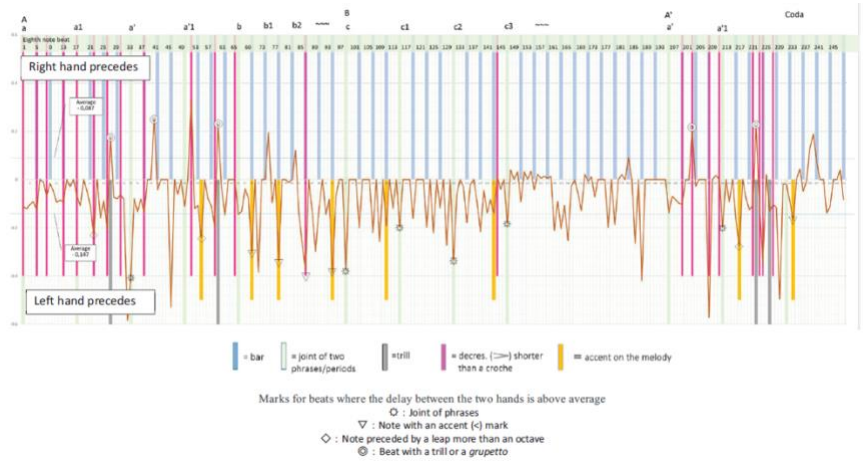
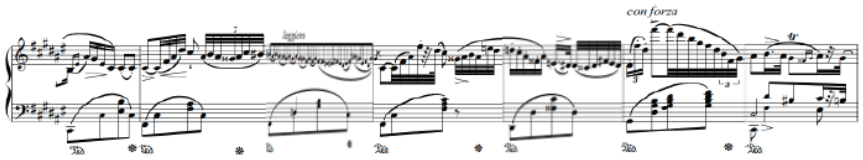


Figure 2 Gaps between melody and accompaniment, Nocturne *Op*.15 No.2 of F. Chopin performed by C. Saint-Saëns (Welte-Mignon piano roll, 1905).



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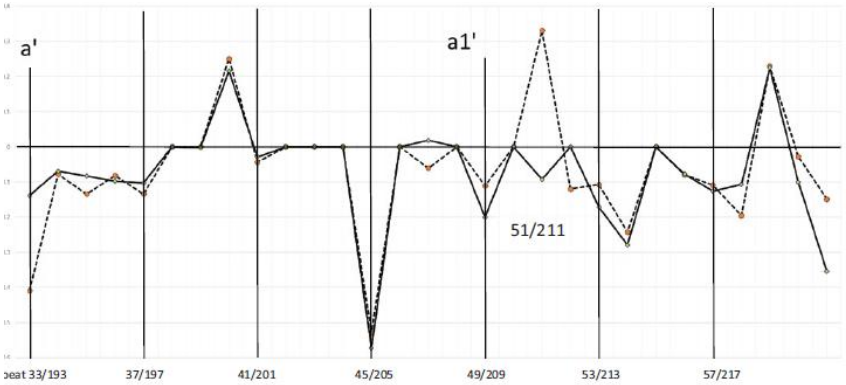

Figure 3. Timing gap between melody and accompaniment, comparison between recording and score

3.1.1 What are the specific features of Sonic Visualizer that are most useful for classical performers in analyzing recording performances?

Table 1. Elaborates on the important aspects and details of the explanation.

Aspect	Details
Tempo Analysis	Sonic Visualizer allows detailed analysis of tempo, enabling performers to scrutinize the timing of notes in a performance. This is particularly useful for understanding the timing gaps between melody and accompaniment, as illustrated in Ueda's study of Saint-Saëns' performance
MIDI Data Conversion	The ability to convert MIDI data and calculate the duration of each note provides performers with precise control over their performance timing. This feature helps in accurately marking the starting points of all notes.
Visual Markers for Beats	Sonic Visualizer's capability to display beat markers (in blue for accompaniment and orange for melody) aids performers in distinguishing between different musical elements and ensuring correct synchronization.
***Rubato* Analysis**	The software's tools facilitate the study of *rubato* (both phrasing and expressive *rubato*), helping performers understand how timing deviations are used expressively in performances.
Detailed Graphical Representation	Visual graphs that display the timing gaps between melody and accompaniment offer a clear visual aid for performers to compare recorded performances with the musical score, as seen in the figures provided in the study.

Bowen's work on performance analysis (Ueda, 2021) points out the challenges in traditional timing measurements, emphasizing the need for tools like Sonic Visualizer to provide accurate visual markers for better synchronization and analysis. Segnini & Sapp (2005) (Segnini & Sapp, 2005) discuss how the flexibility in tempo and dynamics, which includes *rubato*, can reveal interpretative choices and enhance the emotional impact of performances

Table 1 shows that Sonic Visualizer's capability to display visual markers for beats plays a significant role in performance analysis. The use of different colors for marking beats—blue for accompaniment and orange for melody—helps performers to

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distinguish between various musical elements clearly. This visual aid simplifies the process of ensuring correct synchronization between different parts of the music.

3.1.2 In what ways can Sonic Visualizer aid performers in understanding and analyzing different interpretations of the performance?

In their paper "A Musicologist's Guide to Sonic Visualizer," Cook & Leech-Wilkinson (Cook & Leech-Wilkinson, 2009a) assert that Sonic Visualizer enables users to enhance the precision of their observations, refine their auditory perception, and explore the intricacies of recordings through the use of fundamental computer-based tools. In contrast to traditional review approaches, José Bowen's work 'Tempo, Duration, and Flexibility: Techniques in the Analysis of Performance' (Bowen, 1996) only necessitated the following: The y-axis represents the duration of Beethoven's Fifth Symphony's exposition, measured in minutes, while the x-axis represents the date of the recording. Despite the presence of scattered data points, the overall trend indicates an increase in the tempo of the song. The following chart is displayed in figure 4 below.

Table 2 shows an essential aspect of musical expression, especially in romantic piano music, is the use of rubato. Sonic Visualizer excels in analyzing *rubato*, allowing performers to explore both phrasing rubato and expressive *rubato*. Ueda's analysis revealed how Saint-Saëns skillfully controlled the timing of melody about accompaniment, creating an expressive and dynamic performance. Understanding the use of *rubato* through Sonic Visualizer helps performers appreciate how timing deviations can be employed to enhance musical expression.

Table 2. Elaborates on the important aspects and details of the explanation.

Aspect	Details
Detailed Timing Analysis	By providing a visual and quantitative analysis of timing, Sonic Visualizer helps performers understand the nuances of different interpretations. For instance, Ueda's study on Saint-Saëns' performance reveals how the pianist skillfully controlled the timing between melody and accompaniment to enhance the musical expression.
Identification of *Rubato* Types	Sonic Visualizer allows performers to classify and understand the use of phrasing and expressive rubato in performances. This classification helps in recognizing how different performers use timing variations to emphasize phrases, modulate, and imitate a cantabile style.
Comparison with Musical Scores	The ability to compare the recorded performance with the original score using timing graphs helps performers identify deviations and understand the interpretative choices made by other musicians.
Visualization of Musical Phrases	The visual representation of phrases and periods through rubato analysis helps performers see how certain expressive elements are used to make phrases and periods recognizable, thus aiding in the overall understanding of the interpretative structure of a piece.

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3.2 Review 2

In their paper "A Musicologist's Guide to Sonic Visualizer," Cook & Leech-Wilkinson (Cook & Leech-Wilkinson, 2009a) assert that Sonic Visualizer enables users to enhance the precision of their observations, refine their auditory perception, and explore the intricacies of recordings through the use of fundamental computer-based tools. In contrast to traditional review approaches, José Bowen's work 'Tempo, Duration, and Flexibility: Techniques in the Analysis of Performance' (Bowen, 1996) only necessitated the following: The y-axis represents the duration of Beethoven's Fifth Symphony's exposition, measured in minutes, while the x-axis represents the date of the recording. Despite the presence of scattered data points, the overall trend indicates an increase in the tempo of the song. The following chart is displayed in figure 4 below.

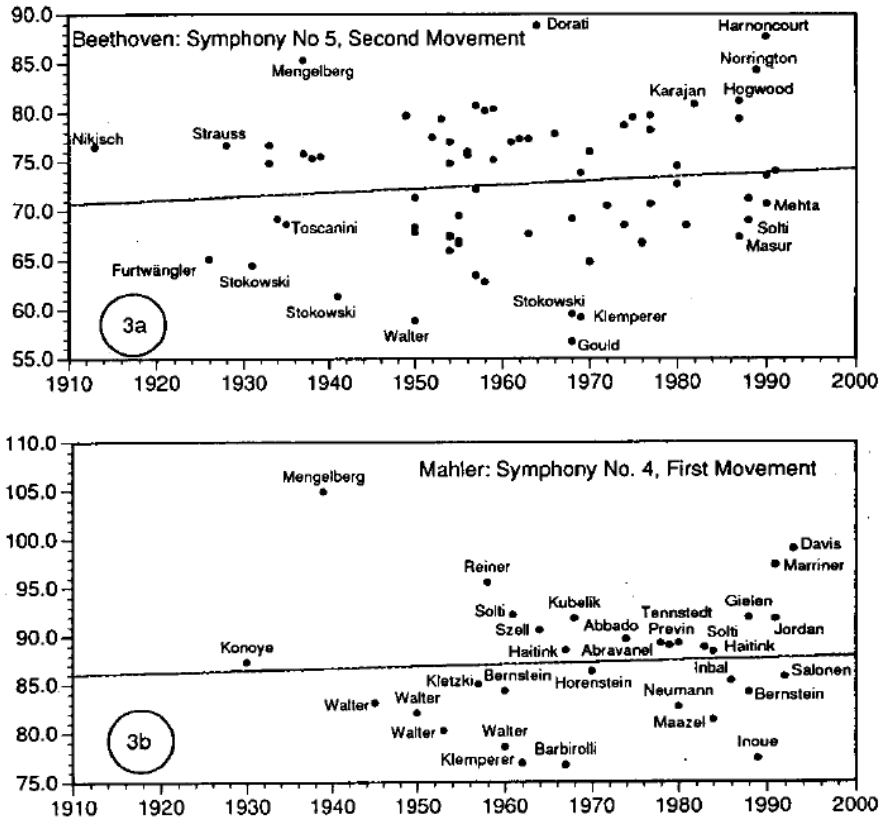

Figure 4. Comparations of Tempo Based on Bowen's approaches

Cook & Leech-Wilkinson (Cook & Leech-Wilkinson, 2009b) have identified two fundamental problems with Bowen's approach. Firstly, there is uncertainty regarding the accuracy of the timing measurements. Secondly, it is challenging to establish a connection between the tempo graphs generated and the actual music while listening to it. Sonic Visualizer effectively addresses these issues and significantly enhances the reliability of the tapping process. In addition, Cook & Leech-Wilkinson's study further

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examines the relationship between tempo and dynamics in Rubinstein's 1939 recording of Chopin's *Op*. 6 No. 1, as depicted in Figure 5.

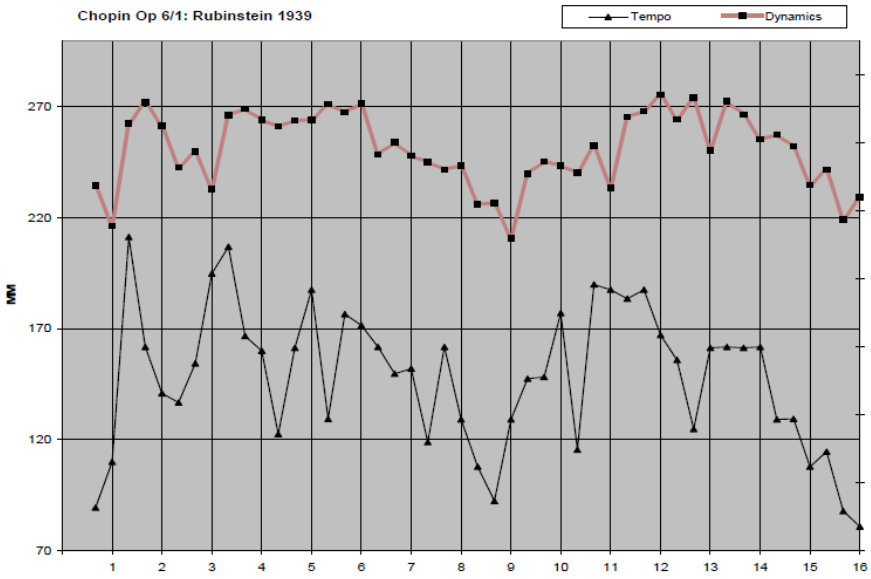

Figure 5. Tempo and dynamic spectrogram

3.2.1 What are the specific features of Sonic Visualizer that are most useful for classical performers in analyzing recording performances?

Table 3. Elaborates on the important aspects and details of the explanation.

Aspect	Details
Tempo Visualization	Enables performers to accurately observe tempo variations and fluctuations during the performance, facilitating comprehension of the use of *rubato* and subtle timing nuances.
Dynamics Visualization	Demonstrates the fluctuations in volume throughout various segments of the composition, facilitating the examination of dynamic manipulation and artistic interpretation.
Synchronized Analysis	Sonic Visualizer's capability to display beat markers (in blue for accompaniment and orange for melody) aids performers in distinguishing between different musical elements and ensuring correct synchronization.
Rubato Analysis	Allows for the simultaneous depiction of tempo and dynamics, offering a deeper understanding of how these two elements interact in a performance.

3.2.1 What are the specific features of Sonic Visualizer that are most useful for classical performers in analyzing recording performances?

Table 4. Elaborates on the important aspects and details of the explanation.

Aspect	Details
Comparative Analysis	Enables performers to juxtapose and analyze several recordings, discerning distinctive interpretive aspects exhibited by each performer.
Identifying Artistic Choices	Assists performers in identifying the locations where there are changes in tempo (*rubato*) and variations in dynamics, guiding them to make comparable or distinct artistic choices.

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Performance Consistency	Sonic Visualizer's capability to display beat markers (in blue for accompaniment and orange for melody) aids performers in distinguishing between different musical elements and ensuring correct synchronization.
Utilizing visual representations of steady and changing portions assists performers in ensuring consistency in both their rehearsal and performance	Analyzing intricate tempo and dynamics graphs, such as Rubinstein's recording, aids musicians in comprehending how to employ tempo and dynamics with expressive intent in their performances.

The features of Sonic Visualizer, particularly tempo and dynamics visualization, provide classical performers with essential tools for analyzing and understanding recordings. These tools help performers gain insights into the interpretative choices of renowned artists like Rubinstein, fostering a deeper appreciation and more nuanced approach to their performances. By enabling comparative analysis and aiding in the identification of artistic choices, Sonic Visualizer supports performers in developing their unique interpretative styles and achieving greater expressiveness in their playing.

3.3 Review 3

Garner's (Garner, 2021) thesis examines five songs from Franz Schubert's song cycle Winterreise (1828) by utilizing spectrographic visuals generated through the Sonic Visualizer computer application. Winterreise is a renowned collection of twenty-four songs composed by Franz Schubert (1797-1828) for voice and piano. Garners claim that examining Winterreise about timbre yields numerous intriguing outcomes as shown in figures 6 & 7. Winterreise is an intensely emotional collection of songs, and Schubert has shown great skill in evoking the emotional depth of Müller's text through his musical compositions. The performance in question features the renowned baritone Dietrich Fischer-Dieskau (1925-2012) and pianist Gerald Moore (1899-1987), which took place in 1955. The score utilized in these analyses was created by Walther Dürr (1932-2018). The paper is structured as a discourse on timbre, including an explanation of spectrographic technology and the establishment of vocabulary to be employed in the analysis.

Figure 6. Schubert's score on Winterreise, II. "Die Wetterfahne," mm. 1–5, phrasing motive marked in blue

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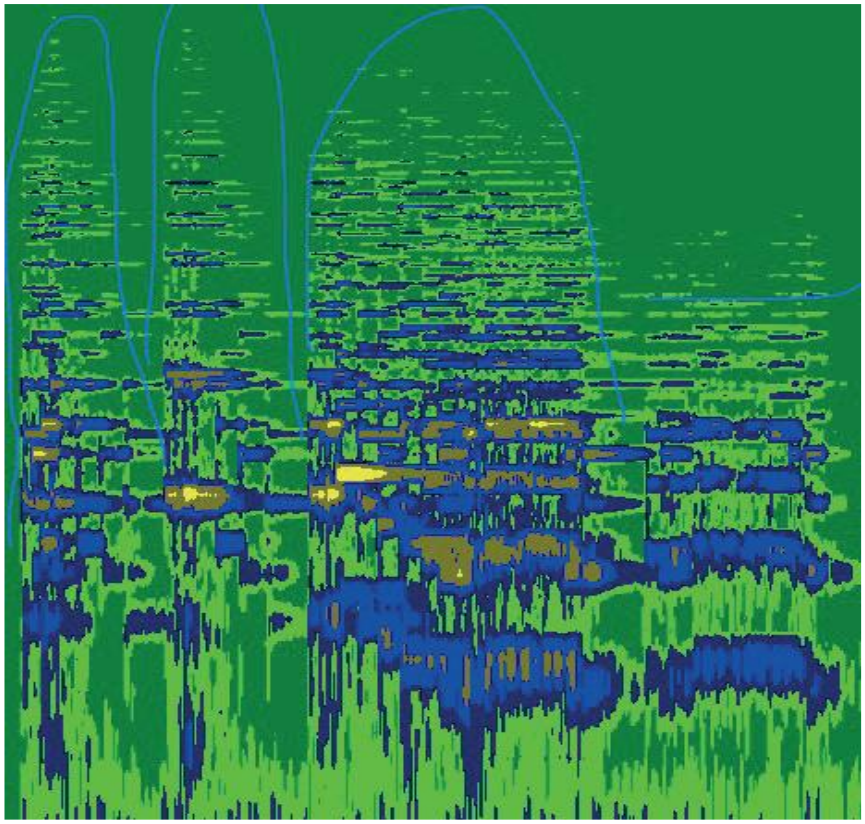

Figure 7. Schubert, Winterreise, II. "Die Wetterfahne," mm. 1–5, phrasing motive marked in blue, spectrogram generated by Sonic Visualizer

3.3.1 What are the specific features of Sonic Visualizer that are most useful for classical performers in analyzing recording performances?

Table 5. Elaborate on the important aspects and details of the explanation.

Aspect	Details
Spectrogram Visualization	Sonic Visualizer creates detailed spectrographic images that visualize the frequency content of the sound over time. This feature is essential for analyzing the timbral characteristics of different instruments and voices.
Harmonic Analysis	The software allows performers to see the harmonic structure of the sound, displaying the fundamental frequencies and overtones. This helps in understanding the richness and complexity of the timbre.
Intensity Mapping	Sonic Visualizer can map the intensity of different frequencies, showing how loudness varies over time and across different harmonics. This helps in analyzing dynamic changes and their effect on timbre.
Frequency Distribution	The distribution of frequencies over time can be visualized, showing how different timbral qualities emerge in the performance. This is useful for identifying bright versus warm tones.

In "Die Wetterfahne," the brighter regions in the higher frequency range likely correspond to the piano's upper register, contributing to a sense of brightness and sharpness in the timbre which is heavily influenced by the harmonic content, and includes the fundamental frequency and its overtones. Table 5 shows that the presence and intensity of these harmonics can be visualized on

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the spectrogram. A richer harmonic content indicates a more complex and nuanced timbre. Analyzing the spectrogram, we can observe the layers of harmonics and how they evolve, indicating the blending of the piano's harmonics with the voice.

Pons, Slizovskaia, Gómez Gutiérrez, and Serra (Pons et al., 2017) emphasize the importance of identifying and analyzing non-harmonic elements using spectrograms. This technique enhances our comprehension of the texture and overall timbre of the performance. Lavengood (Lavengood, 2020) further demonstrates that spectrogram analysis is instrumental in understanding how different timbral qualities are produced. This insight is essential for interpreting the emotional and expressive dimensions of musical performances.

3.3.2 In what ways can Sonic Visualizer aid performers in understanding and analyzing different interpretations of the performance?

Table 6. Elaborates on the important aspects and details of the explanation.

Aspect	Details
Detailed Timbre Analysis	By providing a visual representation of the frequency content, Sonic Visualizer helps performers understand how different timbral qualities are produced. This is crucial for interpreting the emotional and expressive content of the performance.
Comparison of Harmonic Content	Performers can compare the harmonic content of different interpretations, identifying how various artists use harmonics to create distinct timbres. This aids in understanding stylistic differences.
Dynamic Expression Analysis	The intensity mapping feature allows performers to see how dynamics affect timbre, showing the relationship between loudness and timbral changes. This helps in analyzing the expressive use of dynamics. The approaches help in analyzing dynamic changes and their effect on timbre.
Visualization of Musical Phrases	Spectrograms with marked phrases help performers see how musical phrases are articulated and expressed, aiding in understanding the interpretative structure of the pieces.
Identification of Textural Elements	Sonic Visualizer can identify and visualize non-harmonic noise elements, helping performers understand the texture of the performance and how it contributes to the overall timbre. This is important for interpreting the color and mood of the music.

Building on this, Pons, Slizovskaia, Gómez Gutiérrez, and Serra (Garner, 2021) emphasize the importance of identifying and analyzing non-harmonic elements using spectrograms. This technique enhances our comprehension of the texture and overall timbre of the performance. Lavengood (Garner, 2021) further demonstrates that spectrogram analysis is instrumental in understanding how different timbral qualities are produced. This insight is essential for interpreting the emotional and expressive dimensions of musical performances.

The analyses of Table 6 highlight the critical role of spectrograms in dissecting musical performances. Garner's thesis and the study of "Die Wetterfahne" use spectrograms to illustrate the harmonic and dynamic elements, thereby enhancing our

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appreciation of the performance's complexity. Meanwhile, the research by Lavengood (Garner, 2021) extends this understanding by focusing on non-harmonic elements and their impact on timbre and emotional expression. Together, these perspectives underscore the multifaceted utility of spectrogram analysis in musicology, providing a comprehensive tool for exploring both the technical and expressive qualities of music.

3.4 Review 4

In their article "Analysis, Performance, and Images of Musical Sound: Surfaces, Cyclical Relationships, and the Musical Work," Gardiner and Latartara (Gardiner & Latartara, 2007) examine the performances of Russell Sherman (2000) and Wilhelm Kempff (1965) playing the first movement of Beethoven's "Hammerklavier" sonata on a grand piano. Example 4 demonstrates the theme occurring at measures 385-389, whereas image 4 depicts Sherman and Kempff performing measures 385-389. While this texture persists until the conclusion of the movement, for the sake of simplicity in comparison, both Figures 7 and 8 conclude at measure 389.

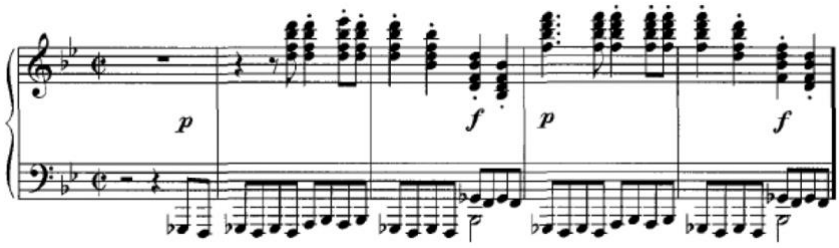

Figure 8. The Score of the first movement of Beethoven's "Hammerklavier mm.385-89

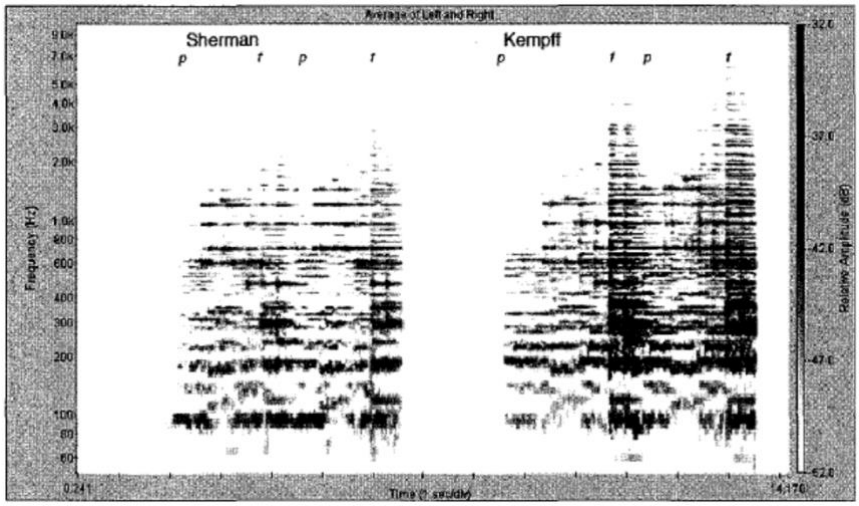

Figure 9. The spectrograph of Sherman and Kempff on the first movement of Beethoven's "Hammerklavier mm.385-89

The analysis of Figure 8 shows that The right hand preserves the initial theme texture, while the left hand executes a notated eighth-note trill, a significant component of this section, resulting in two distinct surface textures. This material has vertical distinctiveness, as there is a four-octave interval between the lowest and highest pitches of the phrase. In contrast to the earlier iterations of the theme, the current rendition features a fluctuation between gentle and intense dynamic levels in the score. Upon examining

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Figure 8, it becomes evident that Sherman and Kempff hold contrasting perspectives regarding how to mold this altered topic. In contrast to Sherman, Kempff demonstrates a significantly wider distinction between the soft and loud dynamics, as evidenced by the prominent upper partial peak in each forte dynamic. While both artists start with a peak in the upper partials at approximately 600 Hz, Sherman's initial strong dynamic reaches up to 2 kHz, and Kempff's reaches up to 4 kHz. In general, Sherman's rendition of this excerpt might be described as cohesive, whereas Kempff highlights the importance of dynamic contrast. These spectrographic images provide a detailed examination of the many methods artists employ when faced with a musical score.

Table 7. Sherman and Kempff Analysis in Performance

Aspect	Sherman's Performance	Kempff's Performance
Theme Presentation	Maintains the initial theme texture with the right hand.	Maintains the initial theme texture with the right hand.
Left-Hand Execution	Executes a notated eighth-note trill, contributing to the section's two distinct surface textures.	Executes a notated eighth-note trill, contributing to the section's two distinct surface textures.
Vertical Distinctiveness	The four-octave interval between the lowest and highest pitches.	The four-octave interval between the lowest and highest pitches.
Dynamic Levels	Displays fluctuations between gentle and intense dynamics.	Displays fluctuations between gentle and intense dynamics.
Dynamic Contrast	Less distinction between soft and loud dynamics.	Significantly wider distinction between soft and loud dynamics.
Spectrographic Analysis	Provides a visual representation showing Sherman's cohesive approach with consistent frequency and dynamic patterns.	Provides a visual representation showing Kempff's approach with more pronounced frequency and dynamic variations.
General Interpretation and Artistic Methods	Described as cohesive, focusing on maintaining a unified texture and dynamic range.	Highlights the importance of dynamic contrast, creating a more pronounced differentiation between dynamics.

Barthet and Dixon (Barthet & Dixon, 2011) describe the use of Sonic Visualizer for creating detailed spectrograms, which display the frequency distribution over time. This allows performers to see the nuances in dynamics and frequency, similar to the way Gardiner and Latartara (Gardiner & Latartara, 2007) compared Sherman and Kempff's performances. By using spectrograms and harmonic analysis, performers can see how different upper partials are emphasized, as Gardiner and Latartara (Gardiner & Latartara, 2007) noted in the dynamic differences between Sherman and Kempff.

4. CONCLUSION

The finding of this study highlights the benefits of using audio-visual tools in classical music performance analysis, demonstrating how these tools can reveal patterns and details that might not be discernible through auditory perception alone. For instance, the analysis of tempo rubato and dynamic contrast in musical performances, as visualized through spectrograms, provides clear evidence of the interpretive choices made by performers. This level of detail helps in answering research questions about the effectiveness of these tools in improving performance and understanding of music. Moreover, the document underscores the

importance of addressing gaps in the existing research, such as the varying effectiveness of Sonic Visualizer across different classical instruments and its impact on performers' interpretative skills. This study reveals some essential attributes of Sonic Visualizer that assist performers:

1) The examination of tempo rubato in Camille Saint-Saëns' rendition of Chopin's Nocturne *Op.*15-2 showcases how Sonic Visualizer's tempo analysis may unveil exact timing variations and emotional components.
2) In Ueda's work, the synchronization of melody and accompaniment is visible to performers through the conversion of MIDI data and the display of visual markers. This functionality enables artists to detect and rectify timing discrepancies with exceptional accuracy.
3) The capacity to analyze rubato and produce intricate visual graphs offers performers a visual depiction of temporal discrepancies and variations in volume, which are essential for comprehending interpretative decisions.

AUTHOR CONTRIBUTION

Herry Rizal Djahwasi: analyzing and processing music literature data, Abdul Rahman bin Safian: collecting music analysis references, Muchammad Bayu Tejo Sampurno: processing and analyzing literature, Zaharul Lailiddin bin Saidon: assisting in reviewing material, Apichai Chantanakajornfun: analyzing and transcribing music analysis results.

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